Guest Lecture: Scalable Visualization

Fri May 21 - Guest: Jeffrey Heer (UW)

Topics

Mon - Tree Visualization

TODAY - Graph Layout: Node-Link Diagrams

TODAY - Alternative Visualizations and Techniques

Select an image to jump to those slides.
Trees and Graphs

**Trees**
Graphs with hierarchical structure
Connected graph with N-1 edges
Nodes as *parents* and *children*

**Graphs**
Model relations among data
*Nodes and edges*
Network Analysis Tasks [Pretorius '13]

**Structure-based:** relationships and connectivity

**Attribute-based:** specific node/link attributes

**Browsing:** understand paths in the data

**Estimation:** summarization and temporal changes
Network Analysis Tasks  [Pretorius '13]

**Structure-based:** relationships and connectivity
Find all of the friends of friends for Taylor.
Find all of the people who are friends with Jordan and Alex.
Six degrees of separation: shortest path between two individuals.

**Attribute-based:** specific node/link attributes

**Browsing:** understand paths in the data

**Estimation:** summarization and temporal changes
Network Analysis Tasks  [Pretorius '13]

**Structure-based:** relationships and connectivity
- Find all of the friends of friends for Taylor.
- Find all of the people who are friends with Jordan and Alex.
- Six degrees of separation: shortest path between two individuals.

**Attribute-based:** specific node/link attributes
- Find all "students" attending CSE412.
- Find all the "friends" and "family" of Alex.

**Browsing:** understand paths in the data

**Estimation:** summarization and temporal changes
Network Analysis Tasks [Pretorius '13]

**Structure-based:** relationships and connectivity
- Find all of the friends of friends for Taylor.
- Find all of the people who are friends with Jordan and Alex.
- Six degrees of separation: shortest path between two individuals.

**Attribute-based:** specific node/link attributes
- Find all "students" attending CSE412.
- Find all the "friends" and "family" of Alex.

**Browsing:** understand paths in the data
- Find Alex's friend Taylor, and then Taylor's friend Jordan.

**Estimation:** summarization and temporal changes
Network Analysis Tasks [Pretorius '13]

**Structure-based:** relationships and connectivity
- Find all of the friends of friends for Taylor.
- Find all of the people who are friends with Jordan and Alex.
- Six degrees of separation: shortest path between two individuals.

**Attribute-based:** specific node/link attributes
- Find all "students" attending CSE412.
- Find all the "friends" and "family" of Alex.

**Browsing:** understand paths in the data
- Find Alex's friend Taylor, and then Taylor's friend Jordan.

**Estimation:** summarization and temporal changes
- How does Jordan's friend group change over the course of the year?
Node-Link Graph Layout
Node-Link Graph Visualization

Nodes connected by lines/curves

**Sugiyama-Style Layout** - arranged by depth

**Force-Directed Layout** - physical simulation

**Attribute-Driven Layout** - arranged by value

**Constraint-Based Layout** - optimization

**Arc Diagrams** - aligned layout
Sugiyama-Style Layout
Sugiyama-Style Layout

Evolution of the UNIX operating system
Hierarchical layering based on descent
GraphViz package!
Produces Hierarchical Layouts

Sugiyama-style layout emphasizes hierarchy. However, cycles in the graph may mislead. Long edges can impede perception of proximity.
Force-Directed Layout
Interactive Example: Configurable Force Layout
Zephoria

User ID: 21721
Friends: 288
Age: ??
Gender: Female
Status: Single
Location: San Francisco, CA
Hometown: Lancaster, PA
Occupation: researcher, social networks, identity, context
Interests: apophenia, observing people, culture, questioning power, reading, Buddhism, spirituality, computer-mediated communication, social networks, technology, anthropology, stamping
Music: psytrance, goa trance (Infected Mushroom, San Kide...)
Books: Digital Structures, Ari D'Ilario, Downtempo, Thievery Corporation, Bath Orchestra, Marnie, Ween, White Stripes
TV Shows: ??
Movies: Kayakandata, Amalio, Waiting Life, Tank Girl, The Matrix, Clockwork Orange, American Beauty, Fight Club, Boys Don't Cry

Member Since: 2003-1-21
Last Login: 2003-1-21
Last Updated: ??

About: Some know me as danah...

I'm a geek, an activist and an academic, fascinated by people and society. I see life as a very large playground and enjoy exploring its intricacies. I revel in life's chaos, while simultaneously providing my own insane element.

My musings: http://www.zephoria.org/thoughts/

Want to Meet: Someone who makes life's complexities seem simply
Use the Force!

http://mbostock.github.io/d3/talk/20110921/
d3.force
7,922 nodes
11,881 edges

[Kai Chang]
Customized Force Layouts

Different forces can be composed to create an expressive space of custom layouts.

A **beeswarm plot** can be made by combining:
- Attractive $X$ and $Y$ forces to draw nodes of a certain category to a desired point
- **Collide** force to detect collision & remove overlap
Attribute-Driven Layout
How many **herbivores** have no **predators**?
How many **herbivores** have no **predators**?
Attribute-Driven Layout

Large node-link diagrams get messy!
Is there additional structure we can exploit?

*Idea:* Use **data attributes** to perform layout
For example, scatter plot based on node values

Attributes may be associated with nodes or edges
or may be statistical properties of the graph.

Use dynamic queries / brushing to explore...
Attribute-Driven Layout

The “Skitter” Layout
Internet Connectivity
Radial Scatterplot

Angle = Longitude
Geography

Radius = Degree
# of connections
(a statistic of the nodes)
Drawing all edges is not particularly useful here…
Node layout determined by geographic location. Adjacent edges shown on node selection.
PivotGraph [Wattenberg ’06]

Layout aggregate graphs using node attributes. Analogous to pivot tables and trellis display.
PivotGraph

Node and Link Diagram

PivotGraph Roll-up
<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th>Legacy</th>
<th>Department</th>
<th>Level</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
<td><img src="image3.png" alt="Graph" /></td>
<td><img src="image4.png" alt="Graph" /></td>
<td><img src="image5.png" alt="Graph" /></td>
</tr>
<tr>
<td>Legacy</td>
<td><img src="image6.png" alt="Graph" /></td>
<td><img src="image7.png" alt="Graph" /></td>
<td><img src="image8.png" alt="Graph" /></td>
<td><img src="image9.png" alt="Graph" /></td>
<td><img src="image10.png" alt="Graph" /></td>
</tr>
<tr>
<td>Department</td>
<td><img src="image11.png" alt="Graph" /></td>
<td><img src="image12.png" alt="Graph" /></td>
<td><img src="image13.png" alt="Graph" /></td>
<td><img src="image14.png" alt="Graph" /></td>
<td><img src="image15.png" alt="Graph" /></td>
</tr>
<tr>
<td>Level</td>
<td><img src="image16.png" alt="Graph" /></td>
<td><img src="image17.png" alt="Graph" /></td>
<td><img src="image18.png" alt="Graph" /></td>
<td><img src="image19.png" alt="Graph" /></td>
<td><img src="image20.png" alt="Graph" /></td>
</tr>
<tr>
<td>Location</td>
<td><img src="image21.png" alt="Graph" /></td>
<td><img src="image22.png" alt="Graph" /></td>
<td><img src="image23.png" alt="Graph" /></td>
<td><img src="image24.png" alt="Graph" /></td>
<td><img src="image25.png" alt="Graph" /></td>
</tr>
</tbody>
</table>

**PivotGraph Matrix**
Limitations of PivotGraph

Only 2 variables (no nesting as in Tableau)
Doesn’t support continuous variables
Multivariate edges?
HivePlots
[Krzywinski ‘11]

Nodes (dots) may be replicated.

Nodes sorted on radial axes by network statistics (e.g., by degree).

Different axes may contain different subsets of nodes.

egweb.bcgsc.ca
Constraint-Based Layout
Constraint-Based Layout

Treat layout as an *optimization problem*

Define layout using an *energy model* along with *constraints*: equations the layout should obey.

Use optimization algorithms to solve

**Position Constraints:**
- a must be to the left of b
- d, c, and b must have the same x position
- a, b, and e must have the same y position
Optimizing Aesthetic Constraints

Minimize edge crossings
Minimize area
Minimize line bends
Minimize line slopes
Maximize smallest angle between edges
Maximize symmetry

but, can’t do it all.

Optimizing these criteria is often NP-Hard, requiring approximations.
SetCoLa: High-Level Layout

(1) Define **sets** of nodes based on attributes.
(2) Apply **constraints** to set elements.

**Layout using SetCoLa:**

(1) **ON ALL NODES**
   (i) **POSITION LEFT OF "RBOUND"**
   (ii) **POSITION RIGHT OF "LBOUND"**
(2) **PARTITION TYPE**
   (iii) **PADDING 18**
(3) **COMPOSE SET FROM TYPES**
   (iv) **ORDER BY TYPE**

[Hoffswell '18]
Arc Diagrams
Linear node layout, circular arcs show connections. Layout quality sensitive to node ordering!
For example, the picture above was built from the first line of a very simple piece: *Mary Had a Little Lamb*. Each arch connects two identical passages. To clarify the connection between the visualization and the song, in this diagram the score is displayed beneath the arches.

This diagram visualizes the refrain from the folk song *Clementine*. As you would expect, the refrain consists of multiple repetitions of the same passage—and that is exactly what the diagram shows. The score isn't shown in this diagram since the notes would be too small to read.
Task Analysis
Node-Link Graph Visualization

Nodes connected by lines/curves

**Sugiyama-Style Layout** - arranged by depth

**Force-Directed Layout** - physical simulation

**Attribute-Driven Layout** - arranged by value

**Constraint-Based Layout** - optimization

**Arc Diagrams** - aligned layout
Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout
The Good: Structured-based analysis of hierarchical relationships
The Bad: Browsing and path following due to long edges

Force-Directed Layout
Attribute-Driven Layout
Constraint-Based Layout
Arc Diagrams
Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout
Force-Directed Layout
Attribute-Driven Layout
Constraint-Based Layout
Arc Diagrams
Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout

**The Good:** Structured-based analysis of closely related elements

**The Bad:** Browsing and summarization of dense networks

Force-Directed Layout

Attribute-Driven Layout

Constraint-Based Layout

Arc Diagrams
Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout
Force-Directed Layout
Attribute-Driven Layout
Constraint-Based Layout
Arc Diagrams
Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout
Force-Directed Layout
Attribute-Driven Layout

The Good: Attribute-based analysis tasks
The Bad (Difficult): Designing layouts appropriately

Constraint-Based Layout
Arc Diagrams
Node-Link Graph Visualization

Nodes connected by lines/curves

- Sugiyama-Style Layout
- Force-Directed Layout
- Attribute-Driven Layout
- Constraint-Based Layout
- Arc Diagrams
Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout
Force-Directed Layout
Attribute-Driven Layout
Constraint-Based Layout

The Good: Graph layout based on structural/aesthetic properties
The Bad (Difficult): Selecting constraints appropriately

Arc Diagrams
Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout
Force-Directed Layout
Attribute-Driven Layout
Constraint-Based Layout
Arc Diagrams
Node-Link Graph Visualization

Nodes connected by lines/curves

Sugiyama-Style Layout
Force-Directed Layout
Attribute-Driven Layout
Constraint-Based Layout
Arc Diagrams

The Good: Summarization and comparison of overall structure
The Bad: Order matters for node layout; Structure-based and path following
Limitations of Node-Link Layouts

Edge-crossings and occlusion! Poor scalability....
Administrivia
Final Project

Initial Project Prototype due this Friday May 21st
Prototype Deliverables: must submit link on Canvas

Prototype Expectations:
Outline of the overall project structure
Rough prototypes of visualizations and interactions
Basic descriptive (narrative) text
Discussion of any concerns or plans for next steps

The more content you have on your page, the more specific feedback we can give to refine your project.
Zoom Poll:
Final Project Check-In
Required Reading for Fri 5/21


**Falcon: Balancing Interactive Latency and Resolution Sensitivity for Scalable Linked Visualizations.** Dominik Moritz, Bill Howe, Jeffrey Heer. CHI 2019.

Optional Readings for Week 9

When(ish) is My Bus? User-centered Visualizations of Uncertainty in Everyday, Mobile Predictive Systems

Visual Semiotics & Uncertainty Visualization: An Empirical Study

A Nested Model for Visualization Design and Validation

Design Study Methodology: Reflections from the Trenches and the Stacks
Hierarchical Edge Bundling
Hierarchical Edge Bundling

Bundle edges with varying amounts of tension
Low-level vs. high-level information
Matrix Diagrams
Adjacency Matrices
Summary: Hierarchies & Networks

Tree Layout
Indented / Node-Link / Enclosure / Layers
Focus+Context techniques for scale

Graph Layout
“Sugiyama” Layout
Force-Directed Layout
Attribute-Driven Layout
Constraint Layout
Arc Diagrams
Matrix Diagrams
Quiz Section: Project Check In

Tomorrow, Thursday May 20th

Final Project Check In
Check in with TAs on project progress
Extra chance to ask questions / get help

Up Next: Jane's Office Hour (link on Canvas)